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SUBJECTS:

Form and Efficiency of Incandescent Filaments,

BY CHARLES J. REED.

Telegraph Line Adjustment: Note on a New Gravity Cell,

BY P. B. DELANY.

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ture Coefficients of some Carbon Filaments. (Illustrated.) Prof. W. A. Anthony, of Manchester, Conn —Lead Encased Conductors. (Illustrated.) David Brooks, of Philadelphia.—The Electric Lighting of Passenger Trains. (Illustrated.) Geo. W. Blodgett, of Boston.

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A paper read before the 40th Meeting of the American Institute of Electrical Engineers, New York, November 19, 1889, and discussion thereon; Vice-President Martin in the chair.

FORM AND EFFICIENCY OF INCANDESCENT FILAMENTS.

BY CHARLES J. REED.

If we pass an electric current through any conductor, as a cylindrical wire, its temperature tends to increase by the transformation of electrical energy into heat. If no heat is allowed to escape, the temperature will increase indefinitely, or until the conductor is melted or otherwise destroyed. If the heat is allowed to escape by radiation alone from the surface of the conductor, its temperature will increase only until the rate of loss by radiation is exactly equal to the rate of transformation. By heat we here include all radiant energy, whether of high or low degree.

As the temperature of an incandescent body increases, not only does the actual quantity of radiant energy increase, but its wave lengths diminish. Hence, as experience has shown, after incandescence is reached, increasing the temperature in a given ratio, increases the light emitted in a much greater ratio.

The exact relation between temperature and luminosity is not known, and it is probably not very simple, if such a relation exists at all. The phenomenon of luminosity is really a physiological one and depends partly upon individual optical capacity; some persons being able to see above, and some below the visible spectrum of the average human eye. The radiant energy we call light is one thing. The sensation of luminosity by which we always estimate light is an entirely different thing. A constant source of light may vary greatly in luminosity, according to the condition of the receptive mechanism and its individuality.

But even ignoring the physiological aspect of the question, the nearest approach we have to formulæ for radiation are the approximate empirical formulæ of Dulong and Petit and of Stefan; which are for total radiations of a low temperature and limited range. They cannot apply to light alone, nor even to total radiation of high degree.

It is unfortunate that there exists no instrument more reliable than the retina of the living eye for measuring the intensity of radiant luminiferous energy, and no method of reading the measurements more accurately than individual guesses. We can measure radiant thermal energy of low degree with Langley's bolometer; we can measure radiant actinic energy by the chemical action it produces; and we can measure total radiant energy in a variety of ways; but how can we isolate or measure radiant luminiferous energy? If there were a high temperature thermometer or other instrument for accurately measuring high temperatures, we might attack this problem with some hope of results.

It is sufficient, however, for our present purpose to know what the eye is able to tell us, namely, that increasing the temperature increases the light in a greater ratio. From this it follows that the efficiency of an incandescent filament is some direct function of its temperature above that of the surrounding space.

Granting that the efficiency increases with increased temperature, we have now to determine whether the efficiency does or does not depend upon any other conditions. It has frequently been claimed that the efficiency depends upon the form of the filament, whether it be cylindrical, flat or square. At a meeting of this Institute of June 8, 1886, for instance, this was by general consent considered an established fact.[2] Others have asserted, but without giving any proof, that the efficiency depends upon the pressure; some claiming that low-tension series lamps and others that high-tension multiple lamps are the more efficient. Others, again, have claimed that at the same pressure and with the same shaped filament, lamps of greater candle-power have a different efficiency from lamps of smaller power.

The trouble seems to have been that we are not always careful to distinguish between efficiency and convenience or adaptability. Each individual finds that a certain form of filament or a certain method of distribution gives better satisfaction than another or is more suited to his purpose, and soon persuades himself that it is "more efficient" than any other.

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[2] Trans. Am. Inst. E. E, vol. IV, p. 20–23.

In order to study the effects of these various conditions upon the efficiency of a filament, it will be convenient to eliminate the effects which we know will be produced by variations in temperature. We assume, therefore, in this discussion that all the filaments and all parts of the filaments under consideration are at the same temperature.

Let T represent this temperature and T', the temperature of the supposed vacuous space surrounding the filament. We must assume further that the material of which the filaments are constructed is perfectly homogeneous in itself and that it is uniform in all the various forms of filaments considered.

Let S denote the specific radiating power of the material at the temperature, T, and S', its specific resistance at the same temperature.

Any variation in S or S' might affect the efficiency, and for this very reason experimental proof is very difficult to obtain. Comparisons of filaments made by different processes are entirely worthless in determining the effect of form or length of a filament on its efficiency.

It is a difficult matter to produce by the same process two carbons of different sizes and shapes that shall have the same specific radiating power and specific resistance at the same temperature, and to produce them by different processes is entirely out of the question. Any comparison, therefore, of short series filaments with long, multiple filaments of a different manufacture is of no value whatever in settling this question.

Let C, represent the candle-power of any filament at temperature, T.
c, its current,
E, the potential difference at its terminals,
R, its resistance,
r, its radius (considered as a cylinder),
L, its length,
H, the energy received per unit of time,
H', the energy radiated per unit of time.

Since the energy developed in any portion of an electric circuit is proportional to the current and pressure, we have

$$H - K E c, \qquad \ldots\ldots(1)$$

in which K is a constant depending upon the units employed.

If we neglect the small quantity of heat lost by conduction from the ends of the filament to the conducting wires, and assume that the space surrounding the filament is a perfect vacuum, then the entire energy of the current will be expended in radiation, and we have

$$H = H'. \qquad \ldots\ldots(2)$$

Let K' represent a constant depending on $(T - T')$.

The rate of radiation of any surface depends only upon the elevation of its temperature above that of the surrounding space and the specific radiating power of the surface at that temperature. We have, therefore,

$$H = H' = K' S \times 2 \pi r L = K E c. \qquad \ldots\ldots(3)$$

The resistance of any conductor is proportional to its length and inversely proportional to its cross section, and we have

$$R = S' \frac{L}{\pi r^2} \qquad \ldots\ldots(4)$$

From Ohm's law and (4)

$$c = \frac{E}{R} \quad \frac{E \pi r^2}{S' L} \qquad \ldots.(5)$$

By eliminating successively E, c and r from (3) and (5) we get

$$\frac{K' S \times 2 \pi r L}{K c} = \frac{c S' L}{\pi r^2} \text{ or, } \frac{c^2}{r^3} = \frac{2 \pi^2 K' S}{K S'} \ldots.(6)$$

$$\frac{K' S \times 2 \pi r L}{K E} = \frac{E \pi r_2}{S' L}, \text{ or } E^2 r = \frac{2 K' S L^2 S'}{K} \ldots.(7)$$

and

$$\frac{K E c}{K' S \times 2 \pi L} = \sqrt{\frac{c S' L}{\pi E}} \qquad \ldots.(8)$$

From (6)

$$K' S \times 2 \pi^2 r^3 = K S' c^2. \text{ Hence,}$$

$$r = \sqrt[3]{\frac{K S' c^2}{2 K' S \pi^2}} \qquad \ldots.(9)$$

and

$$c = \pi \sqrt{\frac{2 K' S r^3}{K S''}} \qquad \ldots.(10)$$

showing that the square of the current is proportional to the cube of the radius or diameter of the filament for all lamps at constant temperature; and that this relation is independent of the pressure, of the length and resistance of the filament and independent of the candle-power;

From (7) we have

$$K' S \times 2 L^2 S^2 = K E^2 r. \quad \text{Hence,}$$

$$L = \sqrt{\frac{K E^2 r}{2 K' S S'}}, = E \sqrt{r} \sqrt{\frac{K}{2 K' S S'}} \qquad \ldots.(11)$$

and $$r = \frac{L^2}{E^2} \times \frac{2 K' S S'}{K} \qquad \ldots.(12)$$

showing that the ratio of the square of the length to the diameter depends only upon the pressure and is independent of candle-power and resistance;

From (8)

$$K^2 E^3 c = 4 \pi K'^2 S^2 S' L^3. \quad \text{Hence,}$$

$$E = \frac{L}{\sqrt[3]{c}} \sqrt[3]{\frac{4 \pi K'^2 S^2 S'}{K^2}} \qquad \ldots\ldots(13)$$

and $$c = \left(\frac{L}{E}\right)^3 \times \frac{4 \pi K'^2 S^2 S'}{K^2} \qquad \ldots\ldots(14)$$

showing that the current is proportional to the cube of the ratio of the length to the pressure.

Since K', S and S' are constant, both the light and the heat radiated will be proportional to the surface and we have

$$C = K'' L \times 2 \pi r \qquad \ldots\ldots(15)$$

in which K'' is a constant depending upon the units employed and upon T.

Hence, $$L = \frac{C}{2 \pi K'' r} \qquad \ldots\ldots(16)$$

and $$r = \frac{C}{2 \pi K'' L} \qquad \ldots\ldots(17)$$

Combining (15) with (3)

$$\frac{K' S C}{K''} = K E c, \text{ or}$$

$$\frac{C}{K E c} = \frac{K''}{K' S} \qquad \ldots\ldots(18)$$

which shows that the candle-power is proportional to the energy, $K E c$; or that the efficiency, $\frac{C}{K E c}$, is constant and independent of the pressure, length, radius, resistance, current and candle-power of the filament. This means that the energy required to produce a given candle-power will be proportional to the candle-power and will be the same, whether it is expended in driving a large current through a short, thick filament, or a small current through a long, slender filament; provided the temperature or state of incandescence is the same and provided no heat is lost by conduction through the terminal wires.

Equation (18) shows also that the efficiency does depend upon K', K'' and S, that is, upon the temperature of the filament, the temperature of the surrounding space and the specific radiating power, and upon them only.

From (18)

$$C = E\,c \times \frac{K\,K''}{K'\,S} \qquad \ldots\ldots(19)$$

$$E = \frac{C}{c} \times \frac{K'\,S}{K\,K''} \qquad \ldots\ldots(20)$$

and

$$c = \frac{C}{E} \times \frac{K'\,S}{K\,K''} \qquad \ldots\ldots(21)$$

From (4)

$$r = \sqrt{\frac{S'\,L}{\pi\,R}} = \sqrt{\frac{S'}{\pi}} \times \sqrt{\frac{L}{R}} \qquad \ldots\ldots(22)$$

and

$$L = \frac{\pi\,r^2\,R}{S'} \qquad \ldots\ldots(23)$$

From (5)

$$E = R\,c \qquad \ldots\ldots(24)$$

From (21) and (24)

$$c = \frac{C}{c\,R} \times \frac{K'\,S}{K''\,K} = \sqrt{\frac{C}{R}} \times \sqrt{\frac{K'\,S}{K''\,K}} \qquad \ldots\ldots(25)$$

We have thus far confined ourselves to the consideration of cylindrical filaments varying in length and diameter. It remains now to show that the efficiency is independent of the form of cross section.

Let us suppose we have a number of lamps, all made of the same material, having the same specific resistance and radiating power, all burning at the same temperature and all giving the same amount of light. Let them be of any pressure and let the cross-section be of any form—circular, elliptical, square, triangular, etc. The filaments will all have equal radiating surfaces; since unequal surfaces of the same character at the same temperature could not radiate equal amounts of light. But equal surfaces of the same character at the same temperature must radiate equal amounts of heat of all wave lengths. Hence, the total amounts of radiant energy are equal. Since the energy received is equal to the energy radiated and the amounts of light are equal, we have

$$C = Q\,E\,c \qquad \ldots\ldots(26)$$

in which Q is a constant, and from (18) we find its value to be

$$Q = \frac{K\,K''}{K'\,S} \qquad \ldots\ldots(27)$$

This shows that the efficiency is independent of the form of cross-section of the filament and depends only upon its temperature, the specific radiating power of its surface, and the temperature of the surrounding space.

When we find, therefore, that one lamp is more efficient than another we must infer, not that it is on account of larger or smaller size, not because it is on a series or on a multiple circuit, not that it is because it has high or low resistance, or a certain form of cross-section, but that it is at a higher temperature, or is made of material having a different specific radiating power.

Of all possible forms of cross-section the circular has the largest area for the same radiating surface per unit of length, and consequently, has the advantage of great strength. The current density will also be less in this than any other form; and hence, any "disintegrating" or "electrolytic effect" of the current, if there is any such, will be least in the cylindrical filament. This will be made clear by supposing a number of lamps of equal candle-power to be burning at the same temperature and pressure, but having various forms of filament, cylindrical, flat, square, etc. We have already seen that these lamps all consume equal amounts of energy, and since they have the same pressure, they must take the same current. Therefore, the filament which has the greatest area of cross section will have the least current density. The fact that the cylindrical filament has the greatest cross-section does not signify that it will require a greater current to keep it at the same temperature. Its form is better adapted for retaining heat than any other. Again, the several lamps will have equal resistances; otherwise they could not take equal currents with the same pressure. From this it follows that the cylindrical filament will be longer and will have less surface and greater mass per unit of length than any other.

A tubular filament would have a greater external diameter, but smaller cross-section of material, and would be shorter than the cylindrical.

The advantages and disadvantages of the various forms may be summed up as follows:—

The cylindrical has the advantage of greater strength and less current density on account of greater cross-section. It has the disadvantage of greater length and fragility.

The tubular filament is strongest in form, being shorter and of greater external diameter than the cylindrical. It has the disadvantage of greater current density than the cylindrical. Both the tubular and the cylindrical have the advantage of uniform illumination in all directions except in and near the plane of the filament.

Flat, or angular filaments have the disadvantage of great current density, and of being unequally heated, since the edges or projecting corners will always be a little cooler[3] than the other parts.

A short, thick filament has the advantage of being stronger and more durable than a long, slender one; but the disadvantage of wasting a greater percentage of heat by conduction through the terminal wires. In this latter respect, it is true, that the long filament is slightly more efficient than the short. A 10-ampere filament, a foot long, would waste no more energy by conduction than a 10-ampere filament an inch long.

Aside from the difficulty of obtaining lamps of different types from different makers which have the same specific resistance and radiating power, there is the difficulty, or rather impossibility, of getting them all to burn at the same temperature, and the difficulty of knowing, even approximately, what that temperature is, and whether it is the same in two lamps or not. For these reasons no experimental comparisons yet published are of any value, either in corroborating or refuting these conclusions. There is one method, however, of testing the formulæ. This method the writer has tried upon some twenty-five different types with the most satisfactory results. The method is as follows:—

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[3] It was asserted before this Institute, June 8, '86, that the edges or corners of a square filament are hotter than the remainder of the surface; but no reason was given. Such a statement scarcely needs refutation, being contrary, not only to established laws, but to the most commonplace and every-day experience. We need only observe the cooling of a square bar of red-hot iron to convince ourselves that the sharp corners are the coolest parts And they would remain the coolest parts even if heat were continually supplied by an electric current to the interior of the bar.

A lamp is constructed with a filament of known dimensions, treated to the required process and exhausted to a certain pressure, as determined by a McLeod vacuum gauge. It is then placed on a circuit of a certain pressure, which gives it a certain desired temperature or efficiency, and the candle-power and current are measured. From the data thus obtained, we calculate by the above equations all the data for lamps of other types. The lamps when made according to this data from the same material, by the same process, and exhausted to the same pressure, should give the calculated candle-power at the calculated pressure.

It must be remembered that the formulæ take no account of the small amount of heat that escapes by conduction through the wires. With lamps of high resistance this may be safely ignored in practice, but in changing from a long to a very short and thick filament it must be taken into account.

The following examples may serve to better illustrate the method—

Let us suppose that a lamp has been constructed to give a certain candle-power on a circuit of given pressure, and it is desired to construct other lampshaving the same efficiency (temperature) and life, but of different candle-power, for the same or for different pressure. We will call this lamp for convenience the zero lamp, and denote its particular values of the variables by the subscript, *o*.

Let $C = C_o = 16$ candles.
$c = c_o = .6$ ampere.
$E = E_o = 100$ volts.
$R = R_o = 167$ ohms.
$L = L_o = 170$ millimeters.
$r = r_o = .07$ millimeter.

The constants K, K', K'', S and S' will have the same value for all values of C, c, E, R, L and r, and hence, will be found by substituting for these quantities the simultaneous values, C_o, c_o, E_o, R_o, L_o and r_o, respectively.

If H is measured in horse-power, we have from (1) $K = \frac{1}{746}$.

From (4)

$$R_o = S' \frac{L_o}{\pi r_o^2} \text{ or}$$

$$S' = \frac{\pi R_{\circ} r_{\circ}^2}{L_{\circ}} = \frac{\pi \times 167 \times (.07)^2}{170} = .015122.$$

from (3)

$$K'\ S = \frac{K\, E_{\circ}\, c_{\circ}}{2\, \pi\, r_{\circ}\, L_{\circ}} = \frac{100 \times .6}{746 \times 2\, \pi\, (.07) \times 170} = .0010757,$$

from (15)

$$K'' = \frac{C_{\circ}}{2\, \pi\, r_{\circ}\, L_{\circ}} = \frac{16}{2\, \pi\, (.07) \times 170} = .21399.$$

Substituting these values of K, K'', S' and $K'\ S$ in equations (4) to (25), we are enabled to solve any problem involving R, E, C, r, c, and L, when any two of the quantities except c and r are given. The equations apply only to lamps of the same material and at the same temperature as the zero lamp. By starting with a lamp of different material, or by burning the same lamp at a different temperature, we obtain a different set of constants, which substituted in equations (4) to (25) adapt them to the changed conditions.

Suppose we wish to construct a lamp of 20 candle-power for a 90-volt circuit:—

$$C = 20.$$
$$E = 90.$$

From (21)

$$c = 3.75 \frac{20}{90} = .8333 \text{ ampere}$$

from (9)

$$r = .098466 \sqrt[3]{(.8333)^2} = .087196 \text{ millimeters}$$

from (11)

$$L = 6.4190 \times 90 \sqrt{.087196} = 170.59 \text{ millimeters}$$

and from (4)

$$R = .0048134 \frac{170.59}{(.087196)^2} = 108.00 \text{ ohms.}$$

The calculations may be verified by substitution in some of the other formulæ.

In constructing the lamp we take a filament 170.59 millimeters long, and of such a radius that, when treated to the given process until at the proper exhaustion it takes .833 ampere with 90 volts, it will have a radius of .0872 mm. If the treatment of the carbon does not increase its diameter, the initial and final radius will be the same; but the radius of the *finished carbon* is to be .0872 mm. When these conditions are fulfilled, we know with certainty that the lamp has the proper temperature if it gives 20 candles. If any single condition is not fulfilled we know with the same certainty that the lamp has not the proper temperature. If two or more of the required conditions are simultaneously not fulfilled, then we know nothing about the resulting temperature.

We are thus enabled to construct lamps of uniform life for varying conditions of current and candle-power; and also to regulate the length of life and the efficiency, increasing or diminishing either the life or the efficiency at pleasure to suit the requirements of particular conditions, remembering always that the life and efficiency are inverse functions of each other.

The fact that the life of most commercial lamps is very irregular, shows that either the material or the temperature is not uniform, and hence, that there is lack of uniformity either in the process or in the dimensions. The writer has examined a number of different makes of lamps, and found that they generally vary in length and cross-section enough to produce serious differences in temperature.

Suppose, again, we wish to construct a 50-candle lamp for a series circuit of 5 amperes:

$$C = 50.$$
$$c = 5.$$

From (20)

$$E = 3.75 \times \frac{50}{5} = 37.5 \text{ volts.}$$

from (9)

$$r = .098466 \sqrt[3]{(5)^2} = .28792 \text{ millimeter}$$

from (11)

$$L = 6.419 \times 37.5 \sqrt{.28792} = 129.16 \text{ millimeters}$$

from (4)

$$R = .0048144 \frac{129.16}{(.28792)^2} = 7.5 \text{ ohms.}$$

In this case the loss of heat by conduction through the connecting wires is considerable, and must be taken into account.

The above equations are not limited to incandescent filaments, but apply equally to any conductor which may be kept at a cer tain fixed temperature by an electric current. By using the proper constants, useful formulæ may be derived for calculating conductors, so that under given conditions they will be heated to a required temperature.

DISCUSSION.

Prof. Edward L. Nichols:—Every one, I think, who is interested in the study of incandescent lamps will be very glad to hear reiterated the fact, which I think none of us will desire to question, that efficiency is a function of the temperature and not a function of the shape of the carbon and of the various other things to which it has often been ascribed. I think there can be no question on this point. It seems to me the clearest point that we have in reference to radiant energy—that the thing which we must get in order to get increased efficiency is higher temperature, and that any method that will enable us to do this will enable us to increase the efficiency. That the temperature of the lamp cannot be measured to-day is probably true. I have seen, however, within a few weeks, a paper by H. F. Weber, of Zurich, which leads me to believe that the day is much nearer than we thought when we shall be able to express the efficiency of any incandescent body in terms of its temperature directly. Mr. Weber has worked out a formula which he has applied to a great variety of examples where the temperature could be measured; that is, he has gone over the literature of incandescence and has selected all those experimental investigations which can be said to be quantitative in any fair sense of the word. Almost all the experiments deal with platinum, because platinum is a substance of which we know quite accurately the law of expansion under change of temperature, and also the law of resistance with change of temperature. These various methods, however, have not been regarded as directly comparable; but Mr. Weber seems to have been able to get out a formula which can be applied to each of them separately. They are found to fall into line beautifully, so that he has put to a very severe test the formula which he proposes; and in the article to which I referred which appeared in the *Repertorium der Physik*, and which I believe has not been translated into English, he claims that he has applied this formula to a variety of incandescent lamps, with great success. I hope this may be true. I am sorry to say I cannot give the formula itself from memory. It contains two or three constants which are to be determined, but comparatively speaking it is a simple formula. I am in hopes, therefore, that we shall before very long be in a position to modify Mr. Reed's statement, which at the present time is undoubtedly justified—that we do not have means of measuring the temperature of incandescent lamps. The thing, of course, which has led to much confusion in this matter, is the fact that lamps behave very differently towards different observers and at different times, and at different times towards the same observer. I think the point there is largely a matter of vacuum. The formula which we have seen developed this evening assumes either a perfect vacuum or a vacuum which is equally good in all cases, and it is a matter of fact, well known, of course, to all those who work with incandescent lamps, that an apparently slight difference in vacuum—really a very large difference—is the thing which changes altogether the incandescence of the filament. In other words, while conduction is an almost negligible factor in this discussion, convection, even where the amount of air remaining in the bulb is small, is by no means a negligible factor, and the failure to recognize more promptly on all sides this simple relationship is due to the fact that we have to deal with lamps which may be identical in every other respect, and yet which vary quite widely in the matter of exhaustion. I must confess that it is one of the chief difficulties which lie in the way of any one, who will experiment with lamps of this kind. It can be overcome by the use of a pressure gauge measuring the vacuum in each case, but ordinarily as we know, this is not done. I should like to call attention to a very well known method by means of which any one can detect slight differences in temperature in two incandescent lamps, even though he may not be able to express either one of those in degrees centigrade, and that is by means of a very old form of photometer known as the Rumford or shadow photometer. Let any one take two lamps made with the very greatest care by our methods of to-day, and of the same type and marked to give 16 or 20 or whatever candle power it may be, at the same voltage. Set those up so that the light from them will shine upon a sheet of white paper, and interpose a block so as to get partial shadow, there being one portion in complete shadow and two portions in partial shadow. An inspection will show that one of those shadows is always a shade bluer than the other.

Now, this method, I presume, many of you have used. I have used it with very much satisfaction in attempting oftentimes to get two lamps as nearly alike as possible. This method is one which gives a very delicate means of getting relative differences of temperature or at least of determining when two lamps are of precisely the same temperature; so that while we are not in position to express that temperature, we are in position to determine equality of temperature with a considerable degree of accuracy. It seems to me that a formula of the kind presented in this paper, which enables one to calculate, as it does evidently with great readiness, just what the dimensions of a lamp should be, will be of great value.

Mr. Geo. B. Prescott, Jr.—Among the points that I understood Mr. Reed to make, and I am rather afraid I may be in error about it, was this—that one of the advantages of a cylindrical filament or one of circular cross-section over any other form was that the current density would be less, and to illustrate this I understood him to select a number of carbons of all sorts of cross-section, all sorts of shapes of cross-section at the same temperature or rather of the same difference of potential and the same current flowing, showing that the resistance was the same. Now, if they were of the same resistance and the same length, the cross-section must have been alike and I should suppose that the current density would be the same in all events.

Mr. Reed:—They are not the same length. I have stated that the E. M. F. and resistance were the same—the same current at the same potential. Now, they have different areas of cross-section and different lengths, which you will find to be true by inspecting this formula. Of course, if the lengths were the same the formula could not be true. The length bears a certain relation to the other constants.

The Chairman (Vice-President T. C. Martin):—As you will have noted, Mr. Reed in his paper mentioned the fact that the paper itself was called out by a statement made before the Institute in 1886. When Mr. Reed first brought this to my attention it appeared to me that we were not at all wishful to make the publications of the Institute a vehicle for any kind of errors, or heresies, or heterodoxies, and it therefore seemed to me well that he should bring his paper before us on that subject, so that it might be cleared up, no matter how well there might be an understanding on the point in the better informed circles and where the investigation had been pursued to any length. and I think Mr. Reed has certainly rendered us a service in giving us so admirable a paper in so brief and succinct a form as he has given it to us this evening.

There being no other discussion, we will proceed to the next paper upon the programme—that by another member who is well known to you, Mr. Delany. I have much pleasure in asking Mr. Delany to give us his paper on his New Line Adjusting System.

A paper read before the American Institute of Electrical Engineers, New York, November 19, 1889, and discussion thereon.

TELEGRAPH LINE ADJUSTMENT.

BY P. B. DELANY.

I take pleasure in bringing before you this evening an improvement in telegraphy, which, although of recent discovery, has already been proven to be practical and beneficial in its operation. I have called it "The Line Adjusting System." This title is not strictly correct; but it is the most comprehensive one I could think of. The system keeps relays at intermediate stations in a telegraph circuit in adjustment in bad weather.

In this country we call a partial loss of current to the earth "escape" to distinguish that condition from a "ground," which means total loss. The terms "light escape," "heavy escape" and "ground" express the different degrees of depletion of a telegraph wire of its current. Demoralization in the operation of telegraphs is proportioned relatively to each degree. No one who is not, or has not been, a telegrapher can appreciate the trouble and turmoil which a rainy day brings to a telegraph wire, especially to a way wire, such, for instance, as the dispatching wire of a railway on which there are usually a large number of intermediate offices. Light escape means trouble, but heavy escape means chaos. Improvement in insulation has done much toward remedying the difficulty, but perfect insulation cannot be obtained, nor would it be altogether desirable, for then the wire could not in all cases be worked at as high a speed as with the present faulty insulation. What is needed is an insulation constant in its imperfection. So long as bare wires are strung on poles, and rain and sunshine succeed each other, there will be a fluctuating condition of insulation, and consequently an ever-changing current on the line, and, as a matter of course, corresponding changes in the attraction of the relay magnet for its armature. These changes in the magnetic pull necessitate readjustments of the retractile spring, the tension of which must always be regulated so as to allow the armature to move quickly between its limits, in response to the make-and-break of the circuit at the operator's key at any station on the line.

It does not follow, however, that a loss of current through bad insulation means a weakening of the electro-magnetism in all the relays. This is generally the effect near the middle of the line, provided the escape is about equal on either side, but at stations near the ends of the line, where the main batteries are located, a heavy escape means a reduction of resistance of the circuit by the partial ground established beyond them, so that they get the force of the main battery from the terminal near them over a comparatively short circuit. Under such conditions the stations near the ends of the line can work with the near terminal, and stations between, with a very low tension on the retractile spring, while it would be impossible for them to receive signals from the distant terminal, or offices beyond the middle of the line, on the same adjustment. A much higher tension must be put on the spring. On a line having an evenly distributed escape throughout, offices near the middle should not have as much difficulty in adjusting as offices near the ends, provided, of course, that the escape is not so heavy as to leave them insufficient current to work with. It frequently happens, however, that a storm extends only over half the line. Under this condition all the offices on the clear end of the line work with each other on a low adjustment, but require a high adjustment to hear the offices on the storm-bound end of the wire. Operators naturally prefer a low adjustment to a high one. When they are sending, their relay armatures and sounder levers respond promptly to the manipulation of the keys, making the work much easier. With a high adjustment the drag of the sounder click behind the movement of the key renders the manipulation laborious. Hence it is, that an operator who has at one minute been receiving from a distant station, requiring high adjustment, will, when he comes to send a return message, turn down his adjustment, so the sounder will follow his key smoothly. Then if the distant station finds it necessary to stop him, he does not feel the break, but goes right on sending.

I have noticed that nearly all operators, good and bad, are vain of their abilities to send rapidly, and nearly all are ambitious to send faster than the operator at the receiving station can write it down, or, in other words, to "rush" him. This is especially true of young operators; but taking them collectively, I do not think there is a body of craftsmen in existence who work so willingly as telegraphers. Each seems individually impelled to "salt" the man at the other end of the line, if possible, and when he succeeds in making him "break," he mentally records a victory and goes at it again with renewed vigor. To outsiders this self-imposed rapid pace may seem foolish, but to the knight of the key there is great glory in it. The great artist never lived, actor, orator or musician, whose soul was more thrilled at the plaudits of thousands, than is the soul of the expert telegrapher when with faultless and rapid transmission he humbles a great receiver by compelling him to beg for quarter. There is music in it, too, and the pride is pardonable, as every one who has been chained to a mad stream of dots and dashes by the hour in the stilly night, bending all his energies to keep the thread and write it down legibly, will admit. Therefore, it is not to be wondered at that on way lines where ambition and ability are greatly out of proportion, there is always trouble in bad weather. The operators are, in the main, young and inexperienced. The lines, on account of the large number of instruments in the circuits, work hard. There is "breaking in," delay and bad temper. This is especially the case with railway telegraphs, where perfection is most needed. I have never been able to understand the niggardy policy pursued by many great railway corporations toward their telegraph department. Poor pay, overwork, miserable accommodations have been the rule in the past. While money has been lavishly spent on sleepers, buffets and parlor cars, and all kinds of luxurious upholstery and conveniences, to attract the traveller by rail, the rail itself, the safety of the car, train and passengers have been made to depend on the ability of some overworked boy at some far-off way station to resist sleep, at a time when he ought to be snugly tucked away in bed. If the travelling public could look more discriminatingly at the electrical equipment of railroads and take less account of tapestry and tinsel, they would in many thousands of cases, I am sure, change their line. It is an encouraging sign that at last the keystone and foundation of railroading, the telegraph service, is beginning to receive better recognition. Instead of allowing the telegraph department to flounder along under the direction of the master of transportation, or division superintendent of the road, with no electrical knowledge whatever, progressive roads now have superintendents of telegraph, and division operators, who, by their practical training and experience, are making great strides in the improvement of the service. When this plan is carried out generally, and when purchasing agents, who may know all about the various other supplies necessary for running railroads, are relieved from the selection of electrical apparatus, a great improvement will be effected. It may appear all right from the commercial standpoint of the purchasing agent to look upon a relay as a relay, a battery as a battery, and buy those which cost the least, but ten cents in the price of an instrument upon the effectiveness of which lives and property depend from one year's end to another, could not influence a practical telegrapher. Instead of forcing bad iron, bad wire, bad insulation, and clumsy, cheap workmanship into telegraph apparatus, the quality and efficiency of instruments will some day be the prime stipulation. I have seen many telegraph relays rendered almost useless for want of a proper retractile spring. This may seem a very small affair, but it is really very important. It affects the efficiency of the entire outfit and the quality of the service. Upon the quality of a relay spring depends the working of the instrument quite as much as upon the quality of the current, and yet it is only necessary to glance at the apparatus in any telegraph office to almost invariably discover that the relay spring is nearer a straight piece of wire than a spiral, and that a half turn either way will throw the relay out of operation. At the risk of having these few criticisms and suggestions ascribed to interested motives, I earnestly commend them as worthy of consideration.

I will now proceed to explain how a great improvement may be effected in the operation of telegraph lines having any considerable number of way stations. I claim that this improvement is almost as necessary to the dispatching wire as the air brake is to the train. It gives the dispatcher control of all his operators, prevents interruptions and delays, and, if the line can be worked between the terminal stations, all the intermediate offices will be in perfect working order. Their instruments will work as well in bad weather as in good. Operators cannot evade responsibility for neglect of duty or seek refuge behind the excuse that their instruments were out of adjustment on account of the bad condition of the line. Their instruments will always be in adjustment, so long as the terminal offices can communicate. This I will, in a few minutes, demonstrate in a practical way over this miniature line, after a brief reference to the diagram of the circuit and connections which you have.

Fig. 1. shows a telegraph line extending from New York to Philadelphia, with New Brunswick and Trenton as way stations. There might be forty such stations, but these two will suffice for our illustration. The figure shows the ordinary outfit for closed circuit, single current working; the system used almost exclusively in this country, and comprising a relay, sounder, and key, the only adjustment being the *adjuster* A. This instrument consists of a magnet, armature lever, *l*, pawl, *p*, and stops *a* and *b*, ratchet wheel, *r*, on the shaft which carries the trailing finger, *t*, and the circle of segments. Alternating segments are joined to a common plate. Set S form part of the circuit, while set S′, are not connected. but simply serve to make a smooth track for the trailing finger. Beginning at the Philadelphia end, the circuit may be easily traced from the main battery, M B, and key to segment plate, S, upon which the trailer, *t*, rests. From the trailing finger to relay, R, through relays at Trenton and New Brunswick to New York, where it goes from relay, R′, to trailer, *t′*, segment plate, S, to key, main battery, M B, and to earth. The adjuster magnets are in the local circuit with the sounders, SR. Fig. 2 is a diagrammatic view of the switch connections of the adjuster for throwing it in or out of use, as the state of the weather or line may require; MM are the main line wires, LL the locals. The switch is now in neutral position. Of course it is never allowed to remain so in practice, as both the main and local circuits would be broken. Fig. 3 is a perspective view of the instrument, inclosed and ready for use.

Let us assume that the weather is fine, and the line clear. The switch will be thrown to the left. The adjuster will be out of use, the line being connected outside of the trailer and segments, while a small resistance coil, shown on the switch, will be substituted for the adjuster magnet in the local circuit, the battery of which, on account of the adjuster is increased from two gravity cells to five. While the switch is in this position we have the present ordinary organization for working. Now, if a rain storm comes on, an intermediate earth route for the main batteries at New York and Philadelphia is established, and trouble with the

tion of the line. Their instruments will always be in adjustment, so long as the terminal offices are [illegible]. This I will, in a few minutes, demonstrate in a practical way upon this miniature line, after a brief reference to the diagram of the circuits and connections which [illegible] above.

Fig. 1 [illegible] from New York to Philadelphia [illegible] Brunswick [illegible] Trenton [illegible]. There [illegible] each station [illegible] two will suffice for our illustration. The figure shows the ordinary [illegible] for closed circuit [illegible] working; the system [illegible] comprising a relay, sounder, and [illegible] the adjuster. This instrument [illegible] p, and stops a and b, [illegible] the trailing finger, t, and [illegible] segments are joined to [illegible] circuit, while set s', are not connected but simply serve to make a smooth track for the trailing finger. Beginning at the Philadelphia end, the circuit may be easily traced from the main battery [illegible] to segment plate, s, upon which the trailer [illegible]. From the trailing finger to relay, R, through relays at Trenton and New Brunswick to New York, where it goes from relay, R, to trailer, t, segment plate, s, to key, main battery [illegible]. [illegible] adjuster magnets are in the [illegible]. Fig. 2 is a diagrammatic view of [illegible] adjuster for throwing it in or out [illegible] weather or line may require: [illegible]. The switch is now in neutral [illegible]. Of course, it [illegible] allowed to remain so in [illegible] local circuits would be broken [illegible] the instrument, inclosed and ready for use.

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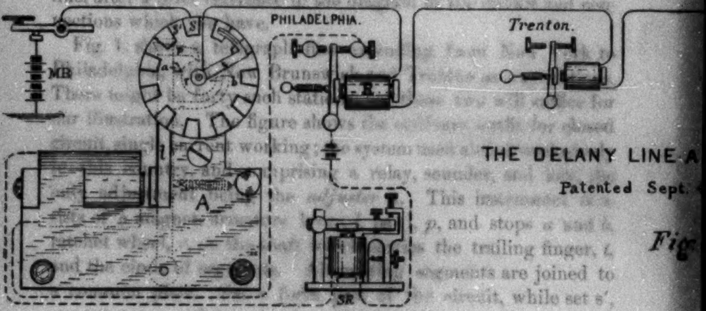
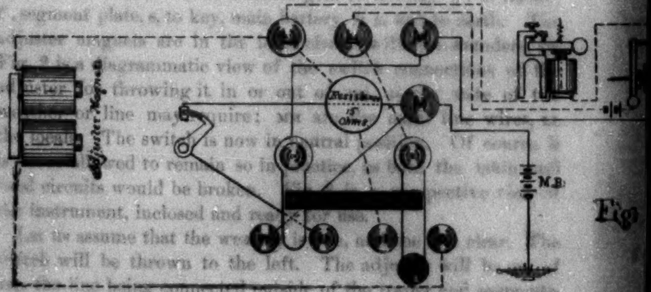


THE DELANY LINE A

Patented Sept.

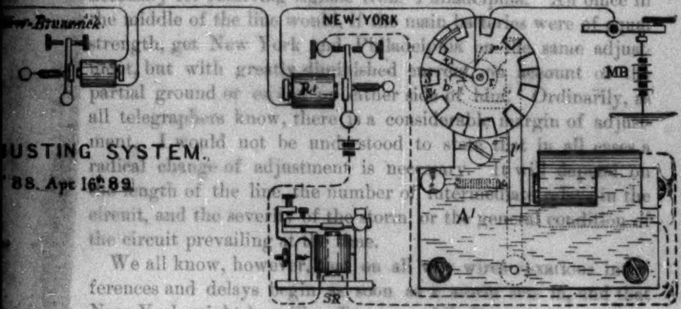
Fig



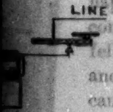
Fig

THE DELANY LINE

adjustment of all the intermediate relays begins. If the escape be evenly distributed, Trenton will hear Philadelphia on a lower adjustment than that required for hearing New York, while New Brunswick will get New York on a lower adjustment than is necessary for receiving signals from Philadelphia. An office in the middle of the line would, if the main batteries were of equal strength, get New York and Philadelphia on the same adjustment, but with greatly diminished [illegible] amount of partial ground or escape on either side of him. Ordinarily, as all telegraphers know, there is a considerable margin of adjustment. I would not be understood to state that in all cases a radical change of adjustment is necessary. [illegible] the length of the line, the number of intermediate [illegible] in the circuit, and the severity of the storm, or the general condition of the circuit prevailing at the time.



We all know, however, [illegible] all [illegible] wire [illegible] ferences and delays [illegible] New York might be calling Trenton, while Trenton, unconscious of the fact, might be endeavoring to get New York. When a few of these careless and inexperienced operators let themselves loose on a long line during bad weather, the use of the wire is practically paralyzed. One of these oblivious free-lances may monopolize it for hours at a time, and it not infrequently happens that two of them, thinking the line idle, will strike up conversation, which an unappreciative and disgusted audience of fellows all along the line must [illegible] while messages of life and death are awaiting t[illegible]rmore, operators cannot read so well when [illegible] on the line, because of the high adjustm[illegible]r relays, and consequent "clipping" of th[illegible]nders, owing to imperfect or light contac[illegible] must "break" and call for [illegible] that rather than do this, they [illegible]ceived signals, the danger of which, especially on railroad lines, all can appreciate. The adjusting system is designed to overcome these difficulties. With what success you will soon have an opportunity to judge.



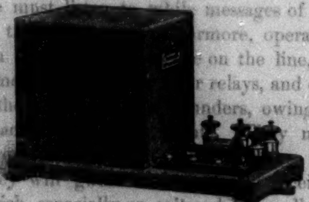


Fig. 3.

JUSTING SYSTEM.

By throwing the switch to the right, the adjuster is instantly in use. If Philadelphia opens his key, and New York be adjusted over the partial ground which I here insert between Trenton and New Brunswick, to represent a rainy day on the

adjustment of all the intermediate relays begins. If the escape be evenly distributed, Trenton will hear Philadelphia on a lower adjustment than that required for hearing New York, while New Brunswick will get New York on a lower adjustment than is necessary for receiving signals from Philadelphia. An office in the middle of the line would, if the main batteries were of equal strength, get New York and Philadelphia on the same adjustment, but with greatly diminished current, on account of the partial ground or escape on either side of him. Ordinarily, as all telegraphers know, there is a considerable margin of adjustment. I would not be understood to state that in all cases a radical change of adjustment is necessary. It will depend on the length of the line, the number of intermediate relays in the circuit, and the severity of the storm, or the general condition of the circuit prevailing at the time.

We all know, however, that on all way wires vexatious interferences and delays begin as soon as a storm sets in, and that New York might be calling Trenton, while Trenton, unconscious of the fact, might be endeavoring to get New York. When a few of these careless and inexperienced operators let themselves loose on a long line during bad weather, the use of the wire is practically paralyzed. One of these oblivious free-lances may monopolize it for hours at a time, and it not infrequently happens that two of them, thinking the line idle, will strike up conversation, which an unappreciative and disgusted audience of fellows all along the line must listen to, while messages of life and death are awaiting transmission. Furthermore, operators cannot read so well when there is heavy escape on the line, because of the high adjustment required for their relays, and consequent "clipping" of the signals on the sounders, owing to imperfect or light contact at the relay points. They must "break" and call for repetitions, and it often happens that rather than do this, they will guess at imperfectly received signals, the danger of which, especially on railroad lines, all can appreciate. The adjusting system is designed to overcome these difficulties. With what success you will soon have an opportunity to judge.

By throwing the switch to the right, the adjuster is instantly in use. If Philadelphia opens his key, and New York be adjusted over the partial ground which I here insert between Trenton and New Brunswick, to represent a rainy day on the line, the New York relay, R′, will be affected, the armature pulled back by its spring, will leave its front stop and break the local circuit, in which are included the sounder and the adjuster magnets, the pawl on the adjuster lever engaging a tooth of the ratchet wheel, *r*, on the shaft carrying the trailer, *t*′, will push the trailer across the blank or dead segment of the plate S′, thereby disconnecting the main battery at New York *for an instant*, during which time there is no battery on the line at either end, and consequently no current to keep the armatures of intermediate relays attracted to their magnets. Therefore, so long as the terminal offices can communicate with each other, all the instruments between will be in adjustment and intercommunication rendered almost as easy as during good weather. The operators at these offices are not only kept aware that the line is in use, but their relays work on a much lower adjustment, notwithstanding that the opening at one end is but for an instant. The armatures of the relays having been released by this short break will not be attracted again readily by the re-establishment of the partial ground, or not until the battery is connected again at both ends, by closing of the key. When an intermediate office is sending, the line is opened at three points, the key, as long as it is held open, and at both ends for an instant.

Now, if you will continue your kind indulgence for a few moments, I will endeavor to give you a practical demonstration of what I have been trying to explain.

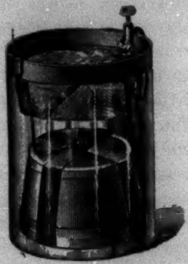
The adjusters are now switched out. We start out with a clear day. All the relays on the line have a normal adjustment and respond to the manipulation of any key Philadelphia is sending. The instruments at Trenton, New Brunswick and New York all receive the signals. By placing a lead from the line and ground wires in this jar of water we have in effect a rain storm, with its centre between Trenton and New Brunswick, making quite a heavy escape. Now, when Philadelphia operates his key, the Trenton instrument speaks up as before, but New Brunswick and New York are silent. New York being a head office, however, has experienced and careful operators who take the precaution to try the relays on a high adjustment to see if anything is going on. Finding the line in use, they adapt the adjustment to the changed condition. Now the adjuster comes into action and wakes up our friend at New Brunswick, who would otherwise be deaf to calls from Trenton or Philadelphia, and would at the same time be a ruthless trespasser if he had a message to send. It will therefore be plain that the instruments at all intermediate offices must work whenever it is possible to work the line from one terminal to another under the most delicate adjustment.

THE CHAIRMAN:—Mr. Delany said "Let us assume that the weather is fine." The operators between New York and Philadelphia this evening would, no doubt, be glad to assume those conditions, and in default of those conditions I have not the least doubt that not only they, but the operators on the long railway lines would be very glad indeed to have placed at their command so valuable an assistance as this which Mr. Delany has brought before us this evening. It is fifty odd years since the telegraph was first introduced and a great many of us are apt to assume that it is perfect. There is probably hardly any electrical invention to-day which is so imperfect as the telegraph, and we have reason to be thankful to such men as Mr Delany for devoting their time and attention and talent to perfecting what has been one of the great inventions of our time. It is important in connection with such a body as the Electrical Engineers that we should impress upon our own constituency as well as the public how large and varied is our field, and I think it could hardly have been done in a more emphatic manner than we have accomplished it this evening, with Mr. Reed at one end of the line discussing incandescent lamps and Mr. Delany at the other showing how important it is that the travelling public should have placed at their service a complete telegraph system. When Mr. Delany promised to give us this paper, it occurred to me that it would be well if he would also favor us with a few remarks on another subject, namely, the gravity cell, to which he has been devoting some attention. One merit of Mr Delany's work in connection with primary batteries is, that he does not claim to light the universe with it. What its demerits are I will now leave him to tell you.

NOTE ON A NEW GRAVITY CELL.

BY P. B. DELANY.

I have taken too much of your time already, and I will make but the briefest reference to this modification of the standard gravity battery. In fact it requires but little explanation. The sulphate of copper is inclosed in the straw board box. The zinc in a paper envelope, and the rim of the jar has attached to it on the inside by a sticky substance, a band of rubber cloth. The advantages claimed for the cell are as follows: When the battery is first set up the dust of sulphate of copper is not instantly dissolved and diffused throughout the liquid, coating the zinc with copper, as is the case with the ordinary cell. Several minutes elapse before discoloration of the fluid begins, and then only at the bottom of the cell, from whence it rises very gradually, never reaching the zinc. If the box be filled, the charge of copper is always uniform. Deposited or spongy metallic copper cannot fall upon the crystals from the zinc, and caking or massing in the bottom of the jar is thus prevented. The copper electrode is held firmly in position, always the same distance from the zinc.



In a battery of any considerable number of ordinary cells it would be difficult to find two alike in this respect. There are little or no stalactic formations from the zinc, and consequently no local action, rendering the battery very useful for open circuit work. When water is poured in to make up for evaporation, the equilibrium of the fluids is not disturbed. The deposit on the zinc thus protected is easily removable, requiring no hacking or scraping. One zinc will endure two charges of sulphate of copper.

The band around the rim is one of the most important features of the cell, as it prevents zinc sulphate from creeping over. It offers simply a mechanical obstruction. It works perfectly in practice. Of course these strips or bands may be applied to any battery requiring them. They serve equally well for Leclanche battery, and to attach them to cells of any kind already up, it is only necessary to see that the rims of the jars are clean and dry. The sticky side of the strip should be heated slightly and pressed on firmly all around.

DISCUSSION.

Mr. C. L. Healy:—I would like to ask Mr. Delany in regard to the resistance of the cell.

Mr. Delany:—I have not had accurate measurements of it, but from the measurements that I have had—they were communicated to me by people who had tried the battery—I find that the resistance is about the same, and the current about the same as in the ordinary gravity cell. You would suppose that the resistance would be increased slightly on account of the paper box and the paper envelope, but you will observe in this battery that the copper electrode is considerably nearer the zinc, and probably that compensates for the intervention of the envelope and the box.

Mr. Healy:—Does the introduction of the adjusting apparatus make any difference with the working of the instrument?

Mr. Delany:—None at all. There is no perceptible lagging. It has been in operation for some years on prominent railways and they make no complaint in that regard.

Mr. R. W. Pope:—I would like to assure our members that Mr. Delany's remarks in regard to the condition of the way lines in this country are no fancy sketch at all. A great many people have an idea that there has been progress in telegraphy as well as other branches, but so far as the way lines are concerned I can speak from actual experience during the past summer, that they are in many cases just as bad or worse than they were twenty years ago. I have learned from some inquiries on the subject that the same care is not taken in keeping up the lines as was formerly the case. This matter of adjustment at way stations comes home to every man, for the reason that all may have occasion some time during our lives to send telegrams to small stations, and it is a fact that very often there are annoying delays that are accounted for by companies on the plea of bad weather. That is taken as something that cannot be prevented; it is an act of God. But here we see a device for preventing a large proportion of this trouble, which, to my own knowledge, has been in practical operation for some time. I have recommended it to some of the railway telegraph superintendents, who have since tried it, and have talked with them about it and found that it is giving perfect satisfaction. In fact, at the meeting of Railway Telegraph Superintendents in Washington one of the gentlemen from Boston said that a storm came up that week and his dispatcher told him that they could not have used the wire at all if it had not been equipped with this device. The difficulty arises from the fact that at the smaller offices the operators do not give constant attention to their instruments. They have multifarious duties in railroad stations—selling tickets, checking baggage and things of that kind, and the instrument is left to take care of itself. They may be away for from half an hour to an hour. In fact I knew of a case this summer where a freight train was detained for an hour, simply because the office where it lay could not get instructions for the train to proceed. It was a bad night, and it is fair to assume that in this case if a system of this kind had been in use they would have had no difficulty. That is, providing the dispatcher's office was manned with sufficient force to take care of all wires. That I am free to confess is not always the case. A great many times an operator is supposed to take care of three or four wires because they do not require constant attention, but as a matter of fact he may be wanted on three or four wires at the same time. The fact that railroad companies do not pay sufficient attention to their telegraph equipment, I think is due, to a certain extent, to the fact that there is little or no revenue from the telegraph service. It is an expense to the road, and being an expense and not a source of revenue, they do not give it that attention that they would if it were an actual revenue-earning part of the system. Of course, it saves them a great deal of expense and a great deal of annoyance, and yet at the same time its importance is not recognized as it would be if it were a profit earning part of the system. That may not be a good reason, but I think it is the reason.

There was one interesting fact came up in connection with this experiment here. It was interesting to me, knowing the circumstances, although it has no bearing on this particular subject. It was necessary to arrange an equipment here of twenty-five cells of carbon battery, and I assured Mr. Delany he would have no trouble in getting them. I went to the Gold and Stock Telegraph Company where, four or five years ago, they had 10,000 cells of carbon battery, and it was with some difficulty they scraped up the number of cells that I wanted. They had all been replaced by the use of dynamo machines. The probability is that if we should want to make a similar exhibition in the course of a year, we should have to go out and buy the cells, and it is quite possible that they may go out of the market altogether.

Prof. Alfred G. Compton:—A question occurs to me—not as an expert at all, but simply as a layman—and I should like to ask Mr. Delany about it. The difficulties along the line occasioned by storms are, of course, increased by the bad condition of the line. I wonder whether putting this adjuster into the hands of the operators may not lead to continued neglect in the care of the lines, and if so, whether by-and-by we might not reach a condition in which, even with the adjuster, we might be unable in bad weather to operate at all. I don't know what the minimum of leakage or demoralization on the line might be under which the adjuster itself might become unmanageable. I should like to hear a word on that.

Mr. Delany:—From the experience on railroads in the past, I don't know but it may come about that the gentleman's fears may be verified but I hope that that objection will not be raised against the introduction of the system. As regards the amount of escape which would entirely prevent communication, that would be hard to determine. It would depend entirely on the length of the circuit and the character of the magnets in the circuit and the number of them, and the total extra induced currents from the magnets and the condition of the wire, its resistance, and the pressure and the current generally that was in use. I think, however, that as soon as the railway companies reach the point when they cannot under any circumstances communicate from one terminal to another, and consequently cannot work with intermediate stations either, probably they will be driven to some expedient to improve the condition of the line.

The Secretary:—I would like to announce to the members that the American Society of Mechanical Engineers is in session in this city, and will be for two days, at No. 12 W. 31st St., the Academy of Medicine. They have invited such of our members as have any desire to be present at their sessions, that they will be pleased to have them attend.

The CHAIRMAN:—As electrical engineers are nine-tenths mechanical engineers, according to the definition that Sir William Thomson has given of the electrical engineer, I have no doubt we ought to derive a good deal of instruction and benefit from those meetings, and I am sure that Prof. Hutton and his fellow officers and the members of the Society of Mechanical Engineers will be glad to welcome our members among them.

I would like to announce that the subject of our next meeting, that of December, is a very important and interesting one, namely, "Transformers," upon which subject we shall have the pleasure of hearing Prof. Ryan, of Cornell University, who is associated with our esteemed Vice-President, Prof. Nichols. This paper will embody some very important valuable data, and will be one of the most interesting papers of the season. The paper following that in January, will be given by Prof. Anthony on a subject yet to be named by him.

Adjourned.

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NAME.	ABBREVIATION.	PUBLISHED, &C.
Engineer.	*Engr.*	London, 163 Strand, weekly. £1.9.
Engineering.	*Eng.*	London, 35-36 Bedford St W. C.; weekly. £1.16.
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The Electrician.	*Lond. Elecn.*	London, 1 Salisbury Court, E. C.; weekly. £1.2.
The Telegraphic Journal and Electrical Review.	*Lond. Elec. Rev.*	London, 22 Paternoster Row, E. C.; weekly. £1.1.8.
The Electrical Engineer	*Lond. Elec. Engr.*	London, 139-140 Salisbury Court; weekly, 17s. 4d.
Nature.	*Nat.*	London, 29 Bedford St., W. C.; weekly, £1.8.
The Electrical Engineer	*N. Y. Elec. Engr.*	New York, 150 Broadway; monthly, $3
The Electrical World.	*Elec. World.*	New York, 167-177 Times Building; weekly. $3
The Electrical Review.	*N. Y. Elec. Rev.*	New York, 13 Park Row; weekly. $3.
The Electric Age.	*Elec. Age.*	New York, 5 Dey Street; semi-monthly, $1.50.
Modern Light and Heat.	*Md Lt. and Ht.*	Boston, 146 Franklin Street; weekly, $3.
Western Electrician.	*West. Elecn.*	Chicago, 6 Lakeside Building; weekly, $3
Electric Power.	*Elec. P'wr.*	New York, 132 Nassau St. monthly, $3.
The Electro-Mechanic.	*Elec. Mech.*	Kansas City, Mo.; semi-monthly, $2.
Practical Electricity.	*Prac. Elec.*	Boston, 620 Atlantic Ave.; monthly, $2.
Journal of the Franklin Institute.	*Jour. Fkln. Inst.*	Philadelphia, Franklin Institute; monthly, $5.
Science.	*Science.*	New York, 47 Lafayette Place, weekly, $3.50.
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